Three planes on merging routes are:
-- different distances from the intersection,
-- traveling at the same speed.
Alternate routes are not available.

LINEUP WITH MATH™

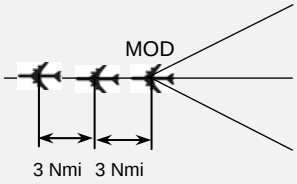
Math-Based Decisions in Air Traffic Control for Grades 5 - 9

Problem Set F

Resolving 3-Plane Traffic Conflicts by Changing Speed

Teacher Guide with Answer Sheets

Overview of Problem Set F



Goal

Estimated class time: 1.5-2 hours

In this Problem Set, students will determine whether three planes traveling on different merging routes will line up with proper spacing at MOD (the last intersection before the planes leave the airspace sector). If the spacing is not adequate, students will change the speed of one or more planes to achieve the proper spacing at MOD. In the final problem, students will make both speed and route changes to achieve proper spacing at MOD.

The planes are traveling at the same altitude and the same constant (fixed) speeds.

This is the most challenging of the *LineUp With Math*™ Problem Sets.

This Problem Set also includes an optimal solution time for each Simulator problem. A "target time" is posted on the Simulator screen. This target time is the minimum required for the last plane to reach the intersection at MOD. An on-screen clock keeps track of the flight time for a student's solution.

Each problem can be explored with the interactive Air Traffic Control (ATC) Simulator. Four of the problems can be more closely examined with Student Workbook F (print-based). The Workbook provides a structured learning environment for exploring the problems with paper-and-pencil worksheets that introduce students to pertinent air traffic control concepts as well as problem analysis and solution methods.

Objectives

Each plane is traveling at 600 knots, the maximum speed allowed. So to resolve a spacing conflict, students must reduce plane speeds.

Students will:

- Analyze a sector diagram to identify spacing conflicts among three planes, each traveling at the same speed.
- Resolve spacing conflicts by changing the speed of one or more planes.
- Resolve spacing conflicts by changing the speed or the speed and route of one or more planes.

Prerequisites

Before attempting the current 3-plane Problem Set, it is *strongly* recommended that students complete Problem Set A that introduces essential air traffic control vocabulary, units, and representations. Students should also complete Problem Sets D and E that introduce speed changes for two planes.

Materials

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- ATC Simulator (web-based)
- Student Workbook F (print-based)

The materials are available on the *LineUp With Math™* website:

http://www.smartskies.nasa.gov/lineup

A separate student website gives students easy access to the Simulator only (and not to the answers and solutions provided on the teacher website):

http://www.atcsim.nasa.gov

ATC Simulator

A complete description of the ATC Simulator is contained in the Educator Guide for LineUp With Math™.

For a Simulator quick start guide and an animated tutorial, visit the LineUp With Math™ website.

Interactive Air Traffic Control Simulator

Students can explore Problem Set F with the interactive ATC Simulator. Each problem features 3-plane conflicts that can be resolved by speed changes or by route and speed changes.

The Simulator problems for Problem Set F are:

3-3*; 3-4*; 3-5*; 3-6*; 3-8; 3-9; 3-10; 3-11; 3-12

Problems with an asterisk (*) are supported by worksheets in Student Workbook F.

An optimal solution time ("target time") is displayed on the screen for each Simulator problem. This target is the minimum time required for the last plane to reach the intersection at MOD. An on-screen clock keeps track of the flight time for student's solution.

For a complete set of answers and solutions to all Problem Set F Simulator problems, see Appendix I of this document.

For a discussion of the key points associated with the first four Simulator problems, see the worksheet notes in the following Student Workbook section.

Student Workbook

It is recommended that you have a copy of Workbook F open while you read these notes.

The worksheet title is the same as the associated Simulator problem.

The Student Workbook consists of four worksheets, one for each of the four featured simulator problems listed below.

Simulator Problem	Worksheet Title
3-3*	Problem 3-3
3-4*	Problem 3-4
3-5*	Problem 3-5
3-6*	Problem 3-6

Each problem features spacing conflicts with different starting conditions. After the first worksheet, the students will require less guidance and structure, and the subsequent worksheets reflect this.

For a complete set of answers to each worksheet, see Appendix II of this document.

For each worksheet, the key points are briefly described as follows.

In the sector diagram, each route flows only towards MOD. E.g., a plane may fly from MINAH to OAL, but cannot fly from OAL to MINAH.

Worksheet: *Problem 3-3: Speed Changes for 3 Planes*

- On a number line, students plot the relative spacing of each plane at MOD to help picture the arrival order of the planes at MOD, their relative spacing, and any spacing violations.
- To identify spacing conflicts, students begin by considering the first and second planes to arrive at MOD. Students determine that the second plane needs 2 additional nautical miles of spacing to achieve Ideal Spacing.
- Next, students identify conflicts between the second plane (with its **new** spacing) and the third plane to arrive at MOD. Students determine that the third plane needs 2 additional nautical miles of spacing to achieve Ideal Spacing.
- To achieve Ideal Spacing at MOD between the first and second planes, students slow the second plane. A 60-knot speed decrease achieves the 2-Nmi additional spacing in 2 minutes. It takes the first plane 3 minutes (30 Nmi at 600 knots) to arrive at MOD. Since Ideal Spacing is achieved after 2 minutes, Ideal Spacing occurs before MOD. In a similar manner, students achieve Ideal Spacing between the second and third planes.

Worksheet: *Problem 3-4: Assure Spacing Among 3 Planes*

- Students use the same problem-solving approach as in Problem 3-3. Minimal structure is provided to lead students to the solution.
- Students first identify spacing conflicts between the first and second planes to arrive at MOD. Then students use the **new** spacing of the second plane to identify the spacing conflict between the second and third planes.

Worksheet: ***Problem 3-5: Assure Spacing Among 3 Planes***

- As in Problem 3-3 and Problem 3-4, students first identify spacing conflicts at MOD and resolve these conflicts to achieve Ideal Spacing (3 Nmi) at MOD.
- In this problem, unlike Problem 3-3 and Problem 3-4, two planes (UAL74 and DAL88) pass through OAL on their way to MOD. Students must determine whether their resolution of the MOD spacing conflict violates the Minimum Separation requirement (2 Nmi) at OAL.
- At the given starting distances (UAL74 is 17 Nmiles from OAL and DAL88 is 18 Nmiles from OAL) and starting speeds, there will be only 1 Nmi of spacing between the planes at OAL. This does not meet the Minimum Separation requirement (2 Nmi). However, after the 60-knot speed reduction for DAL88 (introduced to achieve Ideal Spacing at MOD), DAL88 will achieve an additional 1 Nmi of spacing in 10 Nmiles. So Minimum Separation is achieved before OAL.

Worksheet: ***Problem 3-6: Assure Spacing Among 3 Planes***

- This is the first problem to require students to make a route change **and** a speed change to achieve Ideal Spacing at MOD.
- In this problem, the original positions of two planes, DAL88 (30 Nmi from MOD) and UAL74 (34 Nmi from MOD), will give 4 Nmiles spacing at MOD. This is **more than** the Ideal Spacing (3 Nmi). To achieve Ideal Spacing exactly (for efficiency purposes), students can reroute UAL74 and make a speed reduction.
- With the new route, UAL74 is 31 Nmi from MOD, so an additional 2 Nmiles of spacing are required at MOD. Students can slow UAL74 by 60 knots to achieve the 2 Nmi additional spacing in 2 minutes. Then, to maintain Ideal Spacing and not fall further behind, students can return UAL74 to 600 knots after 2 minutes.
- With the route change and the speed change, UAL74 now has 3 Nmi of spacing with respect to each of the other two planes.

Answer Sheets

For a set of answers and solutions to all Simulator problems, visit the LineUp With Math™ website.

Answer sheets for each of the Problem Set F Simulator problems can be found in Appendix I of this document.

Answer sheets for each worksheet in Student Workbook F can be found in Appendix II of this document.